



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

#10/1100
PPD
5-1000

APPLICANT:

DANIEL KARPEN

TITLE:

MAGNETICALLY SHIELDED FLUORESCENT
LAMP BALLAST CASE

SERIAL NUMBER:

09/096,999

GROUP ART UNIT:

2821

FILED:

JUNE 13, 1998

EXAMINER:

D. VU

DECLARATION UNDER RULE 132

Honorable Commissioner:
Washington, D. C. 20231

Dear Sir:

I, DANIEL KARPEN, a citizen of the United States residing at 3 Harbor Hill Drive, Huntington, N. Y. 11743, do hereby declare as follows:

I am a registered professional engineer, license number 64,966, registered to practice engineering in New York State.

I am the inventor of the invention claimed in the above identified application.

The following is submitted by me in order to demonstrate the superiority of the technology as exemplified in the claim invention.

Interest has been shown in the invention by two manufacturers of fluorescent ballasts. Disclosure agreements are in place with Magnetek, Inc., and with Motorola Corporation. Copies of the disclosure agreements are attached to this declaration as Exhibit "A".

I have written three articles about the claimed invention which have appeared in trade and technical publications.

The first article, entitled "The Need for Electromagnetically Shielded Ballasts", appeared in the November/December 1996 issue of AFE Facilities Engineering.

The second article, entitled "Electromagnetic Fields From Fluorescent Ballasts Solved by Shielding", appeared in Energy Engineering, Volume 94, Number 4, in 1997. The article was considered controversial by the Editor-in-Chief, Wayne Turner, and he wrote a short editorial about the controversy concerning the effects of electromagnetic fields from fluorescent ballasts.

The third article, entitled "Electromagnetic Fields from Fluorescent Ballasts-Human Factor Effect and How to Solve Them", appeared in the 1998 Excellence in Building Proceedings Conference, October 28-31, 1998, of the Energy Efficient Building Association.

These three article are attached as Exhibit "B" to this declaration.

All three article share the same theme: Electromagnetic fields from fluorescent ballasts affect people; there are human factor effects; and the way to solve these problems is to shield the ballast with magnetic shielding materials.

In particular, each of the three articles cites two case studies where solid state ballasts were installed in a library and in a school. In each of the cases, there were human factor effects in terms of headaches, eyestrain, fatigue, and tiredness.

It is not obvious at all that the human factor effects are severe. One first has to eliminate the glare problems from fluorescent lighting by the use of polarizing diffusers, and improve color rendition by using full spectrum fluorescent lamps. As shown in the case study involving the library in Nassau County, there were headaches, eyestrain, fatigue, and tiredness even with the use of the full spectrum lamps and the polarizing diffusers. The remaining human factor effects had to come from the fluorescent ballasts. When I placed a piece of magnetic shielding material over my head, the headaches and other effects from the fluorescent ballasts went away.

The aforementioned publications show that the Applicant has received critical acclaim in the lighting industry, which, when coupled with the 132 Declaration of Myron Kahn, demonstrate the non-obviousness of the Applicant's invention.

In addition, the Applicant further notes that the aforementioned publications were all made after the Applicant first filed the original parent patent application under Serial No. 08/600,400 on February 12, 1996.

The above noted application being appealed to the Board of Appeals was filed on June 13, 1998 under Serial No. 09/096,999, which is more than one year after the Applicant's publication of the article entitled "The Need For Electromagnetically Shielded Ballasts" in the November/December, 1996 issue of the AFE Facilities Engineering journal publication.

It was also filed more than one year after the disclosure of the Applicant's subject matter to Magnetek, Inc. on September 13, 1996 and to Motorola, Inc. on February 13, 1996. These

two disclosures do not constitute public disclosure since they only disclosed what was filed in the originally filed specification filed under Serial No. 08/600,400 of February 12, 1996.

Futhermore, the material contained in the Applicant's publication in Volume 94, No. 4, 1997 of Energy Engineering journal was published in August, 1997, less than one year before the June 13, 1998 filing date of the instant application filed under Serial No. 09/096,999.

Moreover, the material contained in the Applicant's paper before the October 28-31, 1998 Excellence in Building Conference Proceedings was published after the Applicant filed the subsequent application on June 13, 1998 under Serial No. 09/096,999.

Applicant further notes that there was no new matter in the later filed application Serial No. 09/096,999 of June 13, 1998 which was not already in the original parent patent application filed under Serial No. 08/600,400 on February 12, 1996.

There was a discussion in the subsequently filed specification of using conventional adhesive to attach the foil shielding to the ballast, and the existence of holes for conventional wiring to extend through the ballast case.

However, these changes about the use of the holes and the adhesive were already in the originally filed application under Serial No. 08/600,400 in the Amendment of December 1, 1997 and were not objected to as "new matter" by the Examiner in the subsequent Office Action of March 17, 1998.

For example, the changes to the subsequently filed application under Serial Number 09/096,999 which were not in the original patent application filed under Serial Number 08/600,400 are as follows:

As a further example, the title was changed from "ELECTROMAGNETICALLY SHIELDED FLUORESCENT BALLAST" to "MAGNETICALLY SHIELDED FLUORESCENT LAMP BALLAST CASE" because the scope of the text of the originally filed patent application refers to magnetically shielding the ballast case, and the term "electromagnetic shielding" is a minnomer implying more than what is discussed in the original specification describing magnetic shielding of fluorescent lamp ballasts.

In addition, the words "fluorescent lamp" were added before the word "ballast", since the original text had already disclosed shielding the ballasts of fluorescent lamps. Therefore, there is also a new paragraph added to page 1 of the subsequently filed specification under Serial No. 09/096,999 that clarified that "ballast case" refers to a "fluorescent lamp ballast case", and that it can be used for conventional core coil fluorescent lamp ballasts as well as solid state electronic fluorescent lamp ballasts.

There are also several new paragraphs on page 4 of the subsequently filed specification which describe the previously cited prior art of U. S. Patent Nos. 4,393,435 of Petrina, 5,607,228 of Ozaki and 5,446,617 of Blocher.

The "Object and Summary of the Invention" section on page 7 of the subsequently filed specification under Serial

No. 09/096,999 is substantially the same as the "Object and Summary of the Invention" section of the originally filed specification filed under Serial No. 08/600,400. It was rewritten for clarity without the addition of new matter.

Furthermore, as noted above, there are changes on pages 8,9,10, and 17 of the subsequently filed specification filed under Serial No. 09/096,999 that state that the shielding foil material can be attached with adhesive. However, attachment by adhesive is conventional and not a novel feature, and these changes were previously made in the original parent patent application filed under Serial No. 08/600,400 by the Amendment of December 1, 1997 and the subsequently filed substitute specification dated January 30, 1998.

The other changes typed the trade names of the prior art cited products in capital letters, in accordance with Patent Office rules and regulations.

As a result, although the above subsequently filed application under Serial No. 09/096,999 is a continuation-in-part of the originally filed parent patent application filed on February 12, 1996, the added text does not encompass "new matter" not in the originally filed specification.

Therefore, the Applicant's publication in the November/December, 1996 issue of the AFE Facilities Engineering journal publication does not constitute a publication bar under 35 USC 102(b) of the subsequently filed application filed under Serial No. 09/096,999 on June 13, 1998.

The undersigned declares further that all statements made herein of his own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both; under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Date:

April 24, 2000

Daniel Karpen
DANIEL KARPEN

DANIEL KARPEN
PROFESSIONAL ENGINEER & CONSULTANT, P.C.
3 HARBOR HILL DRIVE
HUNTINGTON, NEW YORK 11743

(516) 427-0723

September 13, 1996

Alex Levran
Chief Technology Officer
Magnetek, Inc.
26 Century Boulevard
P. O. Box 290159
Nashville, Tennessee 37229-0159

Pending paper
Dear Alex:

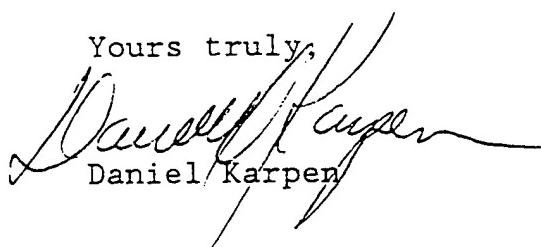
Please find enclosed one copy of my pending patent for an electromagnetically shielded ballast.

I have disclosed this pending patent to one other ballast manufacturer. *marked confidential*

I am also enclosing one copy of an article which has been accepted for publication in a major facilities periodical.

Please contact me if you have any questions.

Yours truly,


Daniel Karpen

MUTUAL CONFIDENTIALITY AGREEMENT

This mutual confidentiality agreement (the "Agreement") is made as of the 12th day of August, 1996 (the "Effective Date") between Daniel Karpen ("Karpen"), an individual, having a principal place of business at 3 Harbor Hill Drive, Huntington, New York 11743, and MagneTek, Inc. ("MagneTek"), a Delaware corporation, having a principal place of business at 26 Century Boulevard, Nashville, Tennessee 37214.

RECITALS

WHEREAS, Karpen and MagneTek are engaged in discussions in contemplation of a business relationship or in furtherance of a business relationship;

WHEREAS, in the course of dealings between Karpen and MagneTek, each party may have access to or have disclosed to it information which is of a confidential nature as that term is later defined in this Agreement; and

WHEREAS, Karpen and MagneTek each desire to establish and set forth their individual obligations with respect to the other's confidential information.

AGREEMENT

In consideration of the foregoing, Karpen and MagneTek mutually agree as follows:

1. Disclosure of Confidential Information. Either party ("Disclosing Party") may disclose to the other party ("Receiving Party"), either orally or in writing, certain information relating to fluorescent ballasts which it believes is confidential ("Confidential Information"). As used herein, Confidential Information means any information provided to Receiving Party by or on behalf of Disclosing Party that might reasonably be considered proprietary, sensitive or private, including but not limited to the following:

(i) Technical information, know-how, data, techniques, discoveries, inventions, ideas, trade secrets, unpublished patent applications, formulae, analyses, laboratory reports, other reports, financial information, studies, findings or other information relating to such party or the technology or methods or techniques used by such party (including notes and memoranda and records prepared by the Receiving Party and

incorporating any such information or material), whether or not contained in samples, documents, sketches, photographs, drawings, lists and the like;

(ii) Data and other information employed in connection with the marketing of the products of such party including cost information, business policies and procedures, revenues and markets, distributors and customers and similar items of information, whether or not contained in documents or other tangible materials; and

(iii) Any other information obtained by the Receiving Party during the term hereof that is not generally known to, and not readily ascertainable by proper means by, third parties.

Information shall not be considered to be Confidential Information unless such information, if provided in tangible form, is clearly marked as being "confidential" or "proprietary," or if provided orally or visually, is summarized in writing to the other party within thirty (30) days of disclosure and clearly indicated as being "confidential" or "proprietary."

2. Confidentiality.

(a) The Receiving Party will use the Disclosing Party's Confidential Information solely to evaluate the commercial potential of a business relationship with the Disclosing Party. The Receiving Party will not disclose the Confidential Information of the Disclosing Party to any person except to its employees or consultants to whom it is necessary to disclose the Disclosing Party's Confidential Information for such purposes. The Receiving Party agrees that the Disclosing Party's Confidential Information will be disclosed or made available only to those of its employees or consultants who have been advised of the terms of this Agreement. The Receiving Party will take reasonable measures to maintain the confidentiality of the Disclosing Party's Confidential Information, and in no event will those measures be less than the measures it uses for its Confidential Information of a similar type. The Receiving Party will immediately give notice to the Disclosing Party of any unauthorized use or disclosure of the Disclosing Party's Confidential Information. The Receiving Party agrees to assist the Disclosing Party in remedying such unauthorized use or disclosure of the Disclosing Party's Confidential Information. Notwithstanding anything to the contrary herein, the Receiving Party shall have no obligation under this Agreement with respect to any information which:

- (i) Is already known to the Receiving Party free of any obligation to treat it as confidential; or
- (ii) Is or becomes publicly available, by other than unauthorized disclosure by the Receiving Party; or
- (iii) Is developed by employees or agents of the Receiving Party independently of and without reference to any Confidential Information of the Disclosing Party (the Receiving Party shall bear the burden of proving such independent development); or
- (iv) Is disclosed to third parties by the Disclosing Party without restriction; or
- (v) Is received from a third party, who is rightfully in possession of the information, without any obligation to treat it as confidential; or
- (vi) Is approved for release by written authorization of the Disclosing Party.

(b) The Receiving Party further agrees that, without the Disclosing Party's prior written consent, Receiving Party will not disclose the existence of this Agreement, its subject matter or the circumstances leading to its adoption to any person (other than its employees and consultants, and then only on a "need to know" basis), nor will Receiving Party contact or attempt to contact any of Disclosing Party's customers or suppliers for the purpose of discussing the contemplated business relationship with the Disclosing Party or its effect upon the customer's or supplier's relationship with the Disclosing or Receiving Party.

3. Compliance with Applicable Law. The provisions of Article 2 shall not be deemed to obligate Receiving Party to do or refrain from doing any act, the doing or not doing of which would cause or reasonably be expected to cause such party to fail to fulfill or comply with any obligation or requirement imposed by any law or regulation; provided, that any disclosures of Confidential Information made to fulfill or comply with any such law or regulation shall be made (i) only after notice to the other party and (ii) under conditions invoking all confidentiality protections as are available by law or regulation.

4. Materials. All materials including, without limitation, documents, drawings, models, apparatus, sketches, designs and lists furnished to the Receiving Party by the Disclosing Party and any tangible embodiments of the Disclosing Party's Confidential Information created by the

Receiving Party shall remain the property of the Disclosing Party. The Receiving Party shall return to the Disclosing Party or destroy such materials and all copies thereof upon the termination of this Agreement or upon the written request of the Disclosing Party.

5. No License. Nothing contained in this Agreement shall be construed as granting or conferring any rights, such as title, license or otherwise, in any Confidential Information disclosed or under any patents, trademarks, or copyrights that are now or subsequently owned by the Disclosing Party. Nor shall the disclosure of Confidential Information constitute any representation with respect to the non-infringement of patents, trademarks, copyrights or any other rights of third parties.

6. Term.

Subject to clause (c) below, either party may terminate this Agreement for any reason by giving notice of termination to the other party. The Agreement shall terminate immediately upon receipt of such notice.

(b) Upon termination of this Agreement, the Receiving Party shall cease to use the Disclosing Party's Confidential Information and shall comply with Article 4 within twenty (20) days of the Termination Date. Upon the request of the Disclosing Party, a representative of the Receiving Party shall certify that the Receiving Party has complied with its obligations in this Section.

(c) Notwithstanding the termination of this Agreement, the Receiving Party's obligations in Article 2 shall survive such termination for a period of three (3) years after disclosure.

7. General Provisions.

(a) This Agreement shall be governed by and constructed in accordance with the laws of the State of Delaware as applied to transactions taking place wholly within Delaware between Delaware residents.

(b) Any notice required to be given under this Agreement shall be deemed received three (3) days after mailing if sent by registered or certified mail to the address of the parties set forth below, or to such other address as either of the parties shall have furnished to the other in writing.

(c) A breach of any of the promises or agreements contained herein will result in irreparable and

continuing damage to the Disclosing Party for which there will be no adequate remedy at law, and the Disclosing Party shall be entitled to injunctive relief and/or a decree for specific performance to prevent the breach of or to enforce the terms of the Agreement, and such other relief as may be proper (including but not limited to monetary damages if appropriate).

(d) This Agreement shall be binding upon and shall inure to the benefit of the parties' successors and permitted assigns.

(e) No term or provision hereof will be considered waived by either party, and no breach excused by either party, unless such waiver or consent is in writing signed on behalf of the party against whom the waiver is asserted. No consent by either party to, or waiver of, a breach by either party, whether express or implied, will constitute a consent to, waiver of, or excuse of any other, different, or subsequent breach by either party.

(f) If any part of this Agreement is found invalid or unenforceable, that part will be amended to achieve as nearly as possible the same economic effect as the original provision and the remainder of this Agreement will remain in full force.

(g) This Agreement constitutes the entire agreement between the parties relating to this subject matter and supersedes all prior or simultaneous representations, discussions, negotiations, and agreements, whether written or oral. This Agreement may be amended or supplemented only by a writing that is signed by duly authorized representatives of both parties.

IN WITNESS WHEREOF, the parties have executed this Agreement as of the Effective Date.

DANIEL KARPEN

Daniel Karpen
3/15/96

MAGNETEK, INC.

By:
Title:

Alexander L 9/10/96

A6077

THE POLICY OF MOTOROLA, INC.
ON IDEAS SUBMITTED BY PERSONS OUTSIDE
THE COMPANY
AND AGREEMENT WITH THE CONDITIONS
UNDER WHICH SUBMITTED.

POLICY AND CONDITIONS

Over the years many ideas for improvements have been voluntarily submitted to us by persons outside of Motorola, Inc. (Company), and we appreciate the confidence in the Company shown by such persons. We do not require that the submitter obtain, or even to have applied for a patent on an idea before submitting the idea. If a disclosure is made under the conditions recited herein, and the Company is interested thereafter in further considering the idea, negotiations will be undertaken to try to arrive at terms which are equitable to both parties and will take care of the needs of the particular situation.

Under our uniform procedure for the submission of all such ideas, two copies of this paper are forwarded to you for your consideration, and if you wish to sign one copy acknowledging your acceptance of the conditions and return it to us with your disclosure, we will be glad at your request to then consider the idea disclosed and inform you of our interest, provided that you as the submitter agree that receipt and consideration of the disclosure by Company does not imply or create:

1. A confidential relationship for any idea submitted to the Company.
2. A promise to pay, inasmuch as Company's obligations to the submitter under all circumstances shall be only those which are made with him in writing; and
3. A recognition by the Company of either novelty or originality.

The Company cannot consider an idea on the condition that it shall return any material submitted if the idea is not found to be of interest. When the material is forwarded to the Company, the submitter should keep a duplicate for his own record, and should any controversy unfortunately arise, this material is necessary as evidence of just what was disclosed to the Company.

If a patent has issued, it is necessary simply to submit a copy of the same with additional comments that might be helpful. If an application

for patent has been filed, a copy of the same can be submitted to the Company for its consideration. Otherwise the disclosure should be by written description and sketches, and all should be sufficiently complete and clear so that the idea can be readily understood.

In whatever form an idea or a patented invention is submitted to the Company, it will be helpful if the submitter will point out what he believes to be new, and will set forth some of the advantages which he thinks his idea has over known devices or processes.

The Company will give a disclosure such consideration as in the judgment of the Company it merits, but in reporting its conclusion can assume no obligation further than to say whether or not it is interested in acquiring patent rights or other rights.

AGREEMENT

(This must be signed by submitter before an idea will be considered by Motorola, Inc.)

I, the undersigned, have read the foregoing statement of policy and the conditions recited, and I understand the statement and agree to said conditions. On such basis, I wish to submit for the Company's consideration an idea on:

(Please describe idea briefly below)
Electromagnetically Shielded Fluorescent Ballasts

Attention: Motorola Lighting, Inc.

And I send you herewith the following attached material disclosing the idea:

(Please enumerate the material forwarded).

Attached is copy of patent application, consisting of specification, drawings and figures, and description of invention.

Daniel Karpen

(Submitter)

Professional Engineer

3 Harbor Hill Drive

(Address)

Date: 2/13/96 Huntington, N.Y. 11743

VIEWPOINT

THE NEED FOR ELECTROMAGNETICALLY SHIELDED BALLASTS

BY DANIEL KARPEN, PE

**Shielding
ballasts
attenuate the
magnetic
components of
fluorescent
ballasts.**

Electromagnetic fields from fluorescent ballasts is a big problem in the interior environment, often mistaken for other problems. Facilities managers and engineers must be made aware of the problem so it can be solved in a satisfactory manner.

Some of the effects of electromagnetic fields on people who work in buildings are sometimes subtle, and in some cases can cause major trouble for building operators and facility managers. The focus of this article will be on the effects of fluorescent ballasts, and in particular, the solid state or electronic ballasts presently coming into the marketplace.

Recently, a Long Island library completed a major lighting retrofit, and one of the problems was that staff and patrons said they could not see; that they were getting headaches, fatigue, tension and eyestrain.

The site was a showcase for energy efficiency. The absolute best materials were specified for installation in this prestigious client. All of the existing fixtures had been removed from the building, and new lighting fixtures containing full-spectrum lamps, polarizing diffusers, specular reflectors and electronic ballasts were installed in the building in order to re-create daylight. In addition, new suspended ceilings were installed in the main reading room. Any discolored acoustical tile was treated to bring it back to its original condition.

The new lighting was totally free of reflected glare, and provided superb color rendition with the full-spectrum lamps. Because of quality materials, the installed lighting load in the building was brought down to about .5 watts per square foot. Electrical energy use in the building is expected to be cut in half, with a savings of \$45,000 per year in the electrical costs in the space of about \$40,000 square feet. The cost of the work was about \$180,000, including engineering fees, providing a payback period of four years. Considering the scope of the work, the payback period was excellent, and with Long Island Lighting Company rates of \$.15 per Kwh, the work had to be done to cut electrical costs.

After validating the complaints myself, I met with the assistant director of the library, who displayed a stack of several hundred complaints. I explained to her that the polarizing diffusers were doing their job in terms of glare reduction, and that the full-spectrum lamps were providing superb color rendition. Measurements were made of the magnetic component of the electromagnetic field

in milligauss, but in most cases, the levels in the building were at the extreme lowest level of sensitivity of my instrument, .3 milligauss, or below that level.

Early in 1994, the New York Power Authority, through its HELP program, converted the fluorescent ballasts in an elementary school on Long Island to T-8 solid state ballasts with new lamps. The original lighting in one kindergarten classroom was warm white fluorescent T-12 standard 40 watt lamps. Since that time, the kindergarten teacher said that of the 19 students, five or six constantly complained about the lighting. These students told their teacher the light was too bright, that it hurt the area over their eyebrows (a common symptom of sensitivity to high magnetic fields) and that they had headaches. The teacher said that of the 32 teachers in the corps of teachers, six or eight of them could no longer wear their contact lenses due to "dry eyes" (a common problem with high magnetic fields).

One lighting manufacturer executive, who put T-8 lamps and ballasts in his office, was constantly getting tension over his eyebrows. When the lights were turned off in his office, the problem went away, even though two computers were kept on. His firm is now committed to providing a new product line of fixtures with electromagnetically shielded ballasts to attenuate the magnetic component of the electromagnetic field.

Recent research has shown that human beings are sensitive to electromagnetic fields, particularly the magnetic component. In order for there to be sensitivity to a magnetic field, there must be a magnetic material, since the only types of materials that can be affected by a magnetic field are magnetic materials. Materials containing iron, nickel, cobalt, alloys or some compounds of these materials, have a susceptibility to magnetic fields. In 1992, Joseph Kirschvink and associates at the California Institute of Technology found magnetite biomagnetization in the human brain. Using an ultrasensitive superconducting magnetometer, they detected the presence of magnetite ferromagnetic material in a variety of tissues from the human brain. They suggest that biogenic magnetite in the human brain may account for a variety of biological effects of low-frequency magnetic fields.

Earlier research by William Rea, a medical researcher at the Environmental Health Center in Dal-

las in 1991 had established an electromagnetic field sensitivity to magnetic fields of varying frequencies from .1 Hertz to 5 million Hertz. Rea found that frequencies of 20,000 Hertz, 35,000 Hertz, and 50,000 Hertz, commonly used in solid state ballasts, affected people just as 60 Hertz fields affect people. Rea also found blurred vision in the presence of electromagnetic fields. In Rea's study, about 25 percent of the patients were found to be sensitive to the fields, and it was concluded that there was strong evidence that electromagnetic field sensitivity exists, and that this sensitivity could be elicited under environmentally controlled conditions.

A SOLUTION TO THE PROBLEM

There are solutions to the problems of electromagnetic fields. The computer industry has tried to reduce the electromagnetic fields from their equipment, and they have been working on the problem for years. However, the lighting industry in particular has not done enough to attenuate the problems of electromagnetic fields from fluorescent ballasts. It should be noted that an incandescent lamp on a non-dimming circuit has virtually non-existent electromagnetic fields. Also it should be noted that the fields from compact fluorescent lamps are quite significant, and this problem has not helped their acceptance into the residential marketplace.

The method I recommended to the library was to put ballast covers around the ballasts to attenuate the magnetic component of the electromagnetic field. These ballast covers are made of a magnetic material. In the design of the electrical circuit for a fluorescent ballast, a transformer, inductor or other magnetic components are included in the ballast. If a fluorescent ballast contains such components, which they usually do, then alternating current flowing through these components gives rise to electromagnetic fields of various frequencies. In a core coil ballast, the magnetic fields are 60 Hertz. There may be multiples of the 60 cycle magnetic fields produced from harmonics in the circuitry.

In the last 10 years, the ballast industry has been shifting to solid state or electronic ballasts. These ballasts contain rectifier and inverters circuits. The inverter circuit provides alternating current generally between 20,000 and 50,000 Hertz to drive the fluorescent lamp. There are three types of inverter circuits. The self excited inverter has the input winding, output winding and feedback winding on the same core. The flip flop occurs because of saturation of the core. These circuits produce strong microphonics, and the external fields are high because of the saturation of the main core on each half cycle. A second type, the separate oscillator excited inverter, has a transformer designed to saturate at 40 Hertz. However, because the transformer is operating at 60 Hertz, it does not saturate at that frequency. It uses a separate oscillator running at 60 Hertz feeding a power transistor. Typically, these circuits produce 20 DB less of external magnetic fields and micro-

phonics. A third type, the self excited with a separate saturable core, has the saturable core wired between the feedback winding of the main core and the input to the power transistor. A small transformer in the feedback circuit does the saturating but carries no substantial power.

Magnetic materials are classified as soft or hard according to their ease of magnetization. Soft magnetic materials are used in devices in which the change in the magnetization during operation is desirable, and these materials are characterized by their low loss and high permeability. A material or metal alloy is "ferromagnetic" if it has at least one of the following elements: iron, nickel or cobalt. Magnetic permeability, or absolute magnetic permeability (μ) is defined as B/H , where B is the flux density produced in the material by the magnetic field, and where H is the intensity of the field. The permeability of ferromagnetic materials is not constant, but is dependent upon the intensity of the magnetic field to which they are exposed. The term "initial magnetic permeability" is defined as the limit approached by the magnetic permeability as B and H are decreased toward zero. Employing a ferromagnetic material having a high initial permeability of at least 2,000 gauss/oersted will function to effectively shield a fluorescent ballast.

Certain alloys of nickel and iron, containing approximately 78 to 80 percent nickel, about 14 to 18 percent iron, and the remainder molybdenum, with proper heat treatment and annealing, have initial permeabilities as high as 300,000. These materials, when used in foil form .002" thick, can provide an attenuation factor of about 200 when used to line the ballast case. Generally, these shielding alloys are effective up to about 100 Kilohertz, and the solid state ballasts have magnetic fields of 20,000 to 50,000 Hertz. There is a way to obtain an 8,000 fold attenuation in the strength of the magnetic fields. Cost considerations come into consideration in the selection of a shielding material and the methodology.

The manufacturer of the offending ballasts in the library case study admitted that there was a problem with the magnetic fields in their F40 ballasts. It said it would be necessary to redesign the circuitry. However, such redesign may not be enough to sufficiently attenuate the magnetic fields.

Facility managers must demand the best products for their facilities. The cheapest way of doing things will always lead to problems down the road. My standard specification for fluorescent lighting now includes shielded ballasts. I would recommend to an owner the removal of any solid state ballasts that do not have shielding, and the replacement of the entire lighting system by full-spectrum lamps, polarizing diffusers and shielded ballasts.

Daniel Karpen of Huntington, New York, has presented many seminars, presentations, papers on full spectrum polarized lighting systems.

*For more information on this article,
circle Reader Service No. 127.*

A Controversy: Publish Controversial Articles or Not?

When I accepted the job as editor of *Energy Engineering*, I expected to make some difficult decisions on what to publish. The first one was made for this issue. I'd like to talk to you about it and ask you to tell me what you think.

The very first article by Mr. Karpen talks about electromagnetic fields from fluorescent ballasts. I had heard some murmurs about this and decided to let the "experts" study it. In the meantime, I'd continued work as always. Then, Mr. Karpen's article crossed my desk. It's crunch time; a decision must be made. Should I publish it or not? I sent the article out for review to someone well versed in the lighting field. The review came back mixed. The reviewer felt the article was well-written; but he / she confessed some ignorance on the subject and *couldn't comment on the health concerns*. In the meantime, Mr. Karpen called me several times wanting to know the status. Two things became obvious. First Mr. Karpen believes in what he wrote, and second, the "experts" may not be sure themselves. Thus, I climb out on a limb and publish.

Obviously, this article does not reflect any official opinion of AEE, *Energy Engineering*, or myself. I publish this in the hopes that the article will spark further articles, research, and/or letters. LET ME KNOW WHAT YOU THINK!! Mr. Karpen, thanks for your persistence. May your hatches be prolific and the trout willing.

Wayne C. Turner, Ph.D., P.E., CEM
Editor-in-Chief

Electromagnetic Fields From Fluorescent Ballasts Solved by Shielding

Daniel Karpen, P.E.
3 Harbor Hill Drive
Huntington, NY 11743
Tel: (516)427-0723

ABSTRACT

Electromagnetic fields (EMFs) from fluorescent lighting, particularly the magnetic component of the EMF, are an unrecognized problem in the interior environment of buildings, often mistaken for other problems such as bad indoor air quality. Facility managers and energy engineers must recognize this problem. Both core coil and solid-state electronic ballasts give off EMFs. The change in the lighting industry from core coil ballasts to solid-state electronic ballasts had changed the nature of the problem, not always for the better. The solution to the problem of EMFs from fluorescent ballasts is to reduce them, particularly the magnetic component of the EMF, and to use appropriate shielding materials. This article also provides a number of anecdotal reports of the serious nature of the problem, which can no longer be ignored by the lighting industry.

ized lighting¹, has enabled building owners to cut the use of electricity for lighting by as much as 87 percent.

The heart of a fluorescent ballast is a transformer. A core coil ballast contains a transformer that operates at 60 hertz. Solid-state ballasts contain circuitry to rectify alternating current to direct current, and an inverter circuit to produce 20K to 65K Hertz alternating current to fire the fluorescent lamp. A solid-state ballast may contain as many as 4 transformers, each with a different function. At least one of transformers in a solid-state ballast operates at high frequency. Some solid-state ballasts contain both a low frequency transformer in the "front end" rectifier circuit, and a high frequency transformer in the "back end" inverter circuit².

The transformers give off an EMF of the frequency that they are operating at. It is now fairly well established that it is the magnetic component of the EMF that affects people³. Evidence to show a cause-effect exists to partially explain how a magnetic field affects people is given later in this article.

There are other impacts from the installation of solid-state electronic ballasts in buildings. For example, electrical interference problems have been noted in time clock systems at schools and universities. A time clock manufacturer has prepared a list of solid-state ballasts that may cause electrical interference problems.⁴ Another well known problem is that anti-theft library book detection systems may fail when electronic ballasts are installed in buildings.⁵ This article will not dwell on these problems; what is important is to discuss the human factors problems. Here is the first case study:

CAST STUDY NUMBER 1

The first case study is a large library in Nassau County on Long Island. A major lighting retrofit had just been completed at the facility. The lighting rehabilitation work involved the installation of new surface-mounted and troffer-mounted fluorescent fixtures containing full-spectrum lamps, polarizing diffusers, specular reflectors, and solid-state electronic ballasts in order to recreate daylight.¹ In addition, new suspended ceilings were installed in the building. Discolored ceiling tile was treated to white and brightened to bring it back to its original condition. The building was beautiful.

INTRODUCTION

In the past fifteen years, solid-state electronic ballasts have moved from a novelty invention made by a few start-up firms to a product that has gained universal acceptance as an energy-saving measure. The adoption of the solid-state electronic ballast, along with other lighting energy conservation measures such as the development of full-spectrum polar-

The new lighting system provided illumination that was free of reflected glare, and the use of full-spectrum lamps provided superb color rendition. The lighting load in the building was brought down to .5 watts per square foot, saving the library \$45,000 annually on its Long Island Lighting Company electric bill for an investment of \$180,000. With rates of \$.15 per kWh, the work had to be done to reduce electrical costs. Overall electrical use in the building was slashed 50 percent.

In spite of these improvements, however, there were a number of problems. The library director called me in after the installation to resolve the complaints. The biggest problem was that the staff and patrons said they could not see. They were having headaches and feeling fatigue, tension, and eye strain. These problems were continuing on a daily basis, with several hundred written complaints made to the facility.

I wanted to determine if the complaints experienced by the building occupants were correct. I surveyed the building and sat down at a library desk to read a magazine. Within minutes I had the same reaction as the occupants of the building.

I suspected that the problem was the magnetic fields from the new solid-state ballasts. I made some measurements of the magnetic fields using a hand-held gaussmeter, but I found that the levels in the building were below the lowest level of the sensitivity of my instrument, .3 milligauss. My suspicion was confirmed, however, when I held a $7.5 \times 9'$ piece of magnetic shielding material above my head and all my symptoms immediately disappeared.

WHAT IS HAPPENING?

A poorly maintained fluorescent lighting system with core coil ballasts can have horrible EMF problems, especially with large numbers of burned-out fluorescent lamps. Lamps with blackened ends tend to cause higher levels of EMFs from the ballasts. Also, 34-watt F40 type lamps have higher levels of electromagnetic fields than standard 40-watt lamps, and U-tube type lamps tend to cause higher levels of EMFs. Fresh standard 40-watt lamps tend to cause the lowest levels of electromagnetic fields for standard fluorescent lighting installations.⁶

The electromagnetic fields from standard fluorescent lighting are 60 Hertz or the harmonics thereof. These fields are abbreviated ELF for Extremely Low Frequency in the EMF literature, which covers the range

from 3 Hertz to about 3,000 Hertz. Solid-state electronic ballasts operate at between 20,000 Hertz and about 65,000 Hertz. The lower level of 20,000 Hertz has been used in the solid-state ballast industry since lower frequencies may be at the upper end of the ability of humans to hear high-pitched sounds. The term VLF for Very Low Frequency from 3,000 Hertz to about 30,000 Hertz will be found in the EMF literature.

Some types of solid-state ballasts produce both ELF and VLF fields. The combined effects of both types of EMFs can be quite bothersome to some people. These ballasts have a 60-cycle "front end" and a high-frequency "back end."

The quality of the components and the design of the ballast circuitry can greatly influence the EMFs from the solid-state electronic ballasts. Some solid-state electronic ballasts have magnetic fields that cannot be felt by any but the most sensitive people, while other ballasts produce fields that bother large numbers of people.⁷ There is no way beforehand of determining whether or not a particular brand of solid-state ballast is going to produce a problem. There are no industry standards for the levels of magnetic fields emanating from solid-state fluorescent ballasts. The research to do so has not yet begun. It should be performed by the United States Department of Energy, which encouraged the ballast industry to produce solid-state electronic ballasts starting in the early 1980s. It is not uncommon for a solid-state ballast manufacturer to unexpectedly change the ballast design, and dramatically change the nature of the EMFs from the ballasts.

OUR RESPONSIBILITY AS ENGINEERS

As energy engineers, we have the responsibility to insure that our designs are visually effective as well as energy efficient. We can no longer pretend that the problem of EMFs from fluorescent ballasts does not exist. It is a real problem, and we must solve it.

Other industries have been working on reducing the EMFs from their products. The computer industry, when it introduced the video display terminal (VDT), had horrible problems with EMFs. The most recent equipment is a vast improvement over the first generation of VDTs. One newspaper publisher of a major suburban newspaper told me that they had to get rid of their early computer terminals because of the EMF problems.⁸

The lighting industry, and in particular the fluorescent ballast manufacturers, must clean up their act. The problems with EMFs have been with us since the introduction of fluorescent lighting about 1940. A diffuser manufacturer told me that when the first fluorescent lighting systems were installed in department stores in New York City, he had horrible vision problems and terrible headaches with what he thought was "glare."⁹ To date, the ballast industry has done almost nothing to reduce the EMFs from their products. Perhaps federal legislation in some of the more progressive states could force the industry to clean up its act. A product liability lawsuit against a ballast manufacturer would certainly have an effect, particularly if a court awarded significant monetary damages. The threat of regulatory action may get an industry to move.

Incandescent lamps on non-dimming circuits have very low EMFs, while the EMFs from compact fluorescent lamps are quite significant. When used as table lamps, the exposure is high.¹⁰ The presence of EMFs has not helped their acceptance in the marketplace. High pressure sodium and metal halide lamps have ballasts that give off EMFs. The new sulfur lamp¹¹ is powered by a ballast, and the EMFs from its ballast will be significant unless the ballast design is changed to reduce them.

OTHER CASE STUDIES

Early in 1994, the New York Power Authority, through its HELP program, converted the fluorescent ballasts in an elementary school in northern Nassau County, Long Island, NY, to T-8 solid-state ballasts with new lamps. The original lighting in one kindergarten classroom was warm white fluorescent T-12 standard 40-watt lamps. Since that time, the kindergarten teacher has kept careful track of her young charges. She said that of 19 students, 5 or 6 constantly complain about the lighting. These five-year-olds provide their own spontaneous opinions about the lighting: "It is too bright in here," "It hurts over my eyebrows" (a common symptom of sensitivity to high magnetic fields), "I have a headache," "I close my eyes to see better," and "Teacher, please turn off the lights."¹² The teacher said that of the 32 teachers in the corps of teachers, 6 or 8 of them can no longer wear their contact lenses due to "dry eyes" (a common problem with high magnetic fields). An older elementary student who wore contact lenses couldn't wear them anymore either.¹² One lighting manufacturer, who is an officer of the firm, put T-8

lamps and ballasts in his office. He told me that he was constantly getting tension over his eyebrows.¹³ When the lights were turned off in his office, the problem went away, even though two computers were kept on.

HOW SENSITIVE ARE PEOPLE TO EMFs?

I performed some anecdotal research of my own to get some information on the sensitivity of various subjects to EMFs. Visitors to my house were brought down into my basement. It is partially dug into the side of a hill, and there is sufficient daylight during the day so artificial illumination is unnecessary. I took a 1F40 strip fixture with a core coil ballast and a cool-white lamp, and put a wooden box around them to stop any light or glare from coming out of the fixture when it was turned on. The fixture is in the shop part of the basement, which has a door and can be closed off from the rest of the basement.

With this arrangement in place and all other electrical equipment in the house turned off, I had my visitors stand 47 feet from the fixture, looking towards it. The door was closed so they could not see me or hear the switch being turned on or off. My observers were able to tell me whether the fixture in the shop was turned on or off from 47 feet away, and they could detect the fixture being turned on or off within one second of my doing so.

I had the Long Island Lighting Company visit my house, and they measured 200 milligauss at the surface of the fixture. At 3 feet away, there was .1 milligauss. As the magnetic field strength drops off as the inverse cube,¹⁴ the strength of the field at 45 feet away is estimated to be between 20 and 40 nanogauss. Yet my observers and I could sense these very weak magnetic fields.

WHAT DO OTHER STUDIES SHOW?

There is a dearth of information on the sensitivity of human subjects to short-term effects of EMFs. Two studies will be cited that are of interest. In order for there to be a sensitivity to a magnetic field, a magnetic material must be present, since the only elements of the periodic table that are susceptible to a magnetic field are iron, nickel, or cobalt, or alloys containing these elements. In 1992, Joseph Kirschvink and associates at the California Institute of Technology found magnetite biomineratization in the human brain. Using an ultrasensitive superconducting magnetom-

eter, they detected the presence of magnetite ferromagnetic materials in a variety of tissues from the human brain. Their research suggested that biogenic magnetite in the human brain may account for a variety of biological effects of low-frequency magnetic fields. The magnetic was found as nanogram-sized masses. Their research must be taken seriously; it was done at a prestigious university, and the findings were published in the Proceedings of the National Academy of Sciences.¹⁵

What about other frequencies and the sensitivity of humans to them? That research was done by William Rea, a medical researcher at the Environmental Health Center in Dallas, Texas. He exposed subjects to magnetic fields of varying frequencies from .1 Hertz to 5 million Hertz. The field strengths were kept constant at about .2 milligauss at hand level while the subjects were tested sitting comfortably upright in a chair. Of the 100 subjects originally recruited for the study, 25 were selected for double-blind testing; these subjects did not react to placebos. These subjects were challenged with EMFs of various frequencies. It was found that of the 21 different frequencies, not all subjects reacted to all 21 frequencies, and on the average there were 11 reactive frequencies per subject.

The principal signs and symptoms produced were neurological (tingling, sleepiness, headache, dizziness, unconsciousness), musculoskeletal (pain, tightness, spasm, fibrillation), cardiovascular (palpitation, flushing, tachycardia, edema), oral/respiratory (pressure in ears, tooth pain, tightness in chest, dyspnea), gastrointestinal (nausea, belching), ocular (burning), and dermal (itching, burning, prickling pain).

Rea found that a number of subjects reacted to the fields produced by the office fluorescent lighting. It should also be noted that of the 25 subjects, 56 percent reacted to 20 Hertz fields, 31 percent reacted to 35K Hertz fields, and 50 percent reacted to the 50K Hertz fields. These fields are the frequencies commonly used in the solid-state electronic ballasts.

Rea's study concluded that there was strong evidence that EMF sensitivity exists, and that this sensitivity could be elicited under environmentally controlled conditions.¹⁶

THE SOLUTION TO THE PROBLEM

I told the library, in a letter about a year prior to being called in to investigate the problems, to have the ballast cases made of a magnetic shielding material. The letter was sent to the architect on the basis of a

problem with solid-state ballasts in a previous job in 1994. The recommendations in the letter were ignored by the architect, the fixture manufacturer, and the library. My ignored advice resulted in the problems that appeared at the job site. Both the architect and the fixture manufacturer thought that I was totally nuts to specify shielded ballasts. In the design of an electrical circuit for a fluorescent ballast, a transformer and inductor, or magnetic components, are included in the ballast. Since a fluorescent ballast contains these components, alternating current gives rise to changing electric and magnetic fields of various frequencies. In core coil ballasts, these fields are 60 Hertz, and there may be much of these fields produced from harmonics in the circuitry.

Solid-state electronic ballasts contain rectifier and inverter circuits. The inverter circuit provides alternating current of frequencies generally between 20,000 and 65,000 Hertz to drive the fluorescent lamps. There are three types of inverter circuits. The self-excited inverter has the input winding, output winding, and feedback winding on the same core. The flip flop occurs because of saturation of the core. These circuits produce strong microphonics, and the external fields are high because of the saturation of the main core on each half cycle. A second type, the separate oscillator-excited inverter, has a transformer designed to saturate at 40 Hertz. However, because the transformer is operating at 60 Hertz, it does not saturate at that frequency. It uses a separate oscillator running at 60 Hertz feeding a power transistor. Typically, these circuits produce 20 dB less of external magnetic fields and microphonics. A third type, the self-excited with a separable saturable core, has the saturable core wound between the feedback winding of the main core and the input to the power transistor. A small transformer in the feedback circuit does the saturating but carries no substantial power.

The method of shielding for the magnetic field is to use a magnetic material. Magnetic materials are classified as soft or hard according to their ease of magnetization. Soft magnetic materials are used in devices where the change in the magnetization during operation is desirable, and these materials are characterized by their low loss and high permeability. A material or metal is "ferromagnetic" if it has at least one of the following elements: iron, nickel, or cobalt. Magnetic permeability, or absolute magnetic permeability, μ , is defined as B/H , where B is the flux density produced in the material by the magnetic field, and where H is the intensity of the field. The permeability of ferromagnetic materials is not constant, but is dependent upon the intensity of the magnetic field to

which they are exposed. The term "initial magnetic permeability" is defined as the limit approached by the magnetic permeability as B and H are decreased towards zero. Employing a ferromagnetic material having a high initial permeability of at least 2,000 gauss/oersted can be used to effectively provide magnetic shielding for a fluorescent ballast.

Certain alloys of nickel and iron, containing approximately 78 to 80 percent nickel, about 14 to 18 percent iron, and the remainder molybdenum, with proper heat treatment and annealing, have initial permeabilities as high as 300,000. These soft magnetic materials, when used for shielding in foil form .002" thick, can provide an attenuation factor of about 200 when used to line the ballast case. Generally, these shielding alloys are effective up to about 100 kilohertz, as the solid-state electronic ballasts have magnetic fields of 20,000 to 65,000 Hertz. There is a method of achieving an 8,000 fold attenuation in the strength of the magnetic fields. Cost considerations come into play in the selection of a shielding material and methodology.

Early in 1996, the author filed a patent application with the United States Patent Office for an electromagnetically shielded ballast to attenuate the magnetic component of the EMFs.

The manufacturer of the offending ballasts in the library case study earlier in this article was made aware of the problems. They were sent an advance copy of this article prior to its publication. They admitted to me that there was a problem with the magnetic fields in their F40 ballasts. They said it would be necessary to redesign the circuitry. However, such redesign may not be sufficient to achieve the necessary attenuation of the magnetic fields.

WHAT TO DO NEXT?

There is a problem out there with the magnetic fields of both core coil and solid-state electronic ballasts. My standard specification for fluorescent lighting now includes magnetic shielding of the ballasts.

My advice to facility managers is not to install any more solid-state electronic ballasts unless they have magnetic shielding. Most of the existing solid-state ballasts that have been installed in buildings in the last ten years are going to have to be removed and replaced by magnetically shielded ballasts.

It is going to cost more money; nothing is cheap. However, if one

About the Author

Daniel Karpen, a recognized expert and a Certified Energy Manager, is a registered Professional Engineer. He has been instrumental in the development of full-spectrum polarized lighting systems. Mr. Karpen has presented many seminars, papers, and talks to various groups on full-spectrum polarized lighting systems. He has three United States patents, several patents pending, and is at the forefront of lighting technology. For further information, contact Daniel Karpen, Professional Engineer, 3 Harbor Hill Drive, Huntington, NY 11743, Tel: (516)427-0723.

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Electromagnetic Fields from Fluorescent Ballasts—Human Factor Effect and How to Solve Them

by Daniel Karpen, P.E.

Abstract

Electromagnetic fields from fluorescent lighting, both core coil ballasted fixtures and high frequency or electronic ballasted fixtures, can have human factor effects. These effects include headaches, eyestrain, tension in the forehead, tiredness, and a sleepy feeling. These effects manifest themselves in various ways and can be mistaken for indoor air quality problems; however, IAQ problems are not to blame. Recent research has suggested that people can feel the magnetic component of the electromagnetic field, not only from 60 cycle line frequencies, but also from 20,000 to 50,000 Hertz magnetic fields from electronic ballasts. The solution to the problem is to electromagnetically shield the ballast by using a thin foil of an iron/nickel alloy to saturate the magnetic component of the electromagnetic field.

Case Study

Let me start this paper with a real case study involving the lighting retrofit of a major community library in central Nassau County on Long Island in New York State. The building had core coil ballasts with cool white lamps. For this 40,000 square foot building, the electrical costs were about \$100,000 per year. The library was paying about \$.15 per Kwh, with the Long Island Lighting Company as their electric utility. The lighting retrofit work involved the replacement of the lighting fixtures in the building, and new lighting fixtures containing full-spectrum lamps, polarizing diffusers, specular reflectors, and solid state electronic ballasts were installed in the building. The ceiling tile was sprayed with a material to whiten and brighten them. A new suspended ceiling was installed in the main reading room. The lighting was beautiful, and recreated daylight. The electrical usage was slashed in half, and the lighting power load in the building was brought down to .5 watts per square foot, including the stack illumination. The project cost of \$180,000 is expected to be recovered in about 3.6 years.

But There Were Problems

In spite of the improvements to the library lighting, there were a number of problems. The library director called me in after the installation to resolve the complaints. The biggest problem was from the staff and the patrons stating that they could not see; that they were getting headaches, fatigue, tension, and eyestrain; that these problems were continuing on a daily basis, with a stack of several hundred written complaints made to the facility.

I explained to the assistant director of the library that the polarizing diffusers were doing their job in eliminating glare, and that the full-spectrum lamps were providing excellent color rendition. I wanted to confirm if the complaints experienced by the building occupants were correct. So I sat down at a library desk to read a magazine. Within minutes, I had the same reaction as the occupants of the building.

I suspected that the problem was the magnetic components of the electromagnetic field from the new solid state ballasts. I made some measurements of the magnetic fields using a hand held gaussmeter, but I found that the levels were below the lowest level of the sensitivity of my instrument, .3 milligauss.

My suspicion was confirmed when I held a piece of a magnetic shielding material 7.5 inches wide by 9 inches in length above my head. When I did that, all the symptoms immediately went away!

What is Going Wrong?

In the past 15 years, the solid state or electric ballast has moved from a novelty made by a few start up firms to a widely accepted energy saving product. The adoption of this product, along with other energy saving technology such as full-spectrum polarized lighting, has enabled the use of electricity for lighting to be cut as much as 87 percent (1).

Every fluorescent ballast contains a transformer. In a core coil ballast, the transformer operates at the line fre-

quency of 60 Hertz. Solid state ballast contain circuitry to rectify alternating current to direct current, and an inverter circuit to provide 20K to 65K Hertz alternating current to power the fluorescent lamp. An electronic ballast may contain as many as 4 transformers, each with a different function. At least one of the transformers in a solid state ballast operates at a high frequency. Some solid state ballasts contain both a low frequency transformer in the "front end" rectifier circuit, and a high frequency transformer in the "back end" inverter circuit (2).

The transformers propagate an electromagnetic field of the frequency that they are operating at. It is now fairly well established that it is the magnetic component of the EMF that affects people (3). Evidence to show a cause effect relationship exists to partially explain how magnetic fields affect people is given later in the paper.

Other Impacts

There are other impacts from the installation of electronic ballasts in buildings. For example, electrical interference problems have been noted in time clock systems at schools, colleges and universities, and hospitals. One time clock manufacturer has prepared a list of solid state ballasts that may cause electrical interference problems with their products (4). Another problem that is fairly well known is that anti-theft devices may fail in library book detection systems when solid state ballasts are installed in library buildings. This paper will not go into detail with these problems, and will only restrict itself with human factor effects. Here is the second case study.

Case Study Number 2

This case study involves an elementary school in northern Nassau County on Long Island in New York State. Early in 1994, the New York Power Authority, through its HELP program, converted the core coil fluorescent ballasts in the school to solid state ballasts with new T-8 lamps. In one kindergarten room, there were warm white lamps driven by core coil ballasts. After the conversion, the classroom kindergarten teacher kept careful track of her young charges. She said of the 19 students in the class, 5 or 6 were constantly complaining about the lighting. The kindergarten students, all 5 years old, became experts in the effects of solid state ballasts. They provided their own spontaneous opinions about the classroom illumination: "It is too bright in here"; "It hurts over the eyebrows" (a common symptom of sensitivity to high magnetic fields); "I have a headache"; "I close my eyes to see better"; and "Teacher, please turn off the lights" (5).

The teacher said of the 32 teachers in the teacher corps, 6 or 8 of them can no longer wear contact lenses due to "dry eyes" (a common problem with high magnetic fields). Also, an older elementary student who wears contact lenses could no longer wear them (5).

What is Happening Here?

A very good question to ask. A poorly maintained fluorescent lighting system driven by core coil ballasts can have horrible electromagnetic field problems, especially if there are large numbers of defective or burnt out lamps. Lamps with blackened ends tend to create higher levels of electromagnetic fields than fixtures with fresh lamps. Also, 34 watt F40 type lamps tend to create higher levels of electromagnetic fields than standard 40 watt lamps, and U-tube type lamps tend to have higher levels of electromagnetic fields than standard 40 watt lamps. From the author's own measurements, it has been found that fresh 40 watt standard lamps have lower levels of electromagnetic fields among lamps powered by conventional core coil ballasts.

The electromagnetic fields from standard fluorescent lighting driven by core coil ballasts are 60 cycle or the harmonics thereof. These fields are abbreviated ELF for Extremely Low Frequency in the EMF literature, which covers the range from 3 Hertz to about 3,000 Hertz.

Electronic ballasts operate from between 20,000 Hertz to about 65,000 Hertz as the upper end frequency, depending upon the circuitry. The lower level of 20,000 Hertz has been used in the electronic ballasts industry since these lower frequencies may be at the upper end of human beings to hear high pitched sounds. The term VLF for Very Low Frequency from about 3,000 Hertz to about 30,000 Hertz will be found in the EMF literature.

Some types of electronic ballasts produce both ELF and VLF fields. The combined effects of both types of electromagnetic fields can be quite bothersome to some people. These ballasts, which include hybrid types, have a 60 cycle front end and a high frequency back end.

The quality of the components and the design of the ballast circuitry can greatly influence the propagation of electromagnetic fields from solid state ballasts. Some electronic ballasts produce electromagnetic fields that can be

only felt by only the most sensitive people, while other models of ballasts produce fields that can bother large numbers of people. There is no way of determining beforehand whether or not a particular model or brand of ballast will produce a problem. There are no industry standards for the levels of magnetic field emanating from solid state or for that matter, from core coil fluorescent ballasts. The research on which to base a standard has not yet been done. It should be performed by a government agency such as the Department of Energy, which has encouraged the development and the growth of the electronic ballast industry. It is not uncommon for a solid state ballast manufacturer to unexpectedly change a ballast design, and also change the nature of the electromagnetic fields emanating from a ballast.

Our Responsibility as Engineers

As Energy Engineers, we have a social responsibility to insure that our designs are not only energy efficient, but visually effective as well. We can no longer duck the problem of electromagnetic fields from fluorescent lighting, as well as other products, and pretend that the problem does not exist. It is a real problem, and we must solve it.

Other industries have been working on the reduction of electromagnetic fields from their products. The computer industry, when it first introduced the Video Display Terminal (VDT), had horrible problems with its products. I know, because I used some of the early VDT's in 1977. The most recent generation of equipment is a vast improvement over the first generation of VDTs. One newspaper publisher told me that they had to get rid of their early computer terminals because of the complaints, and low productivity from their first set of machines.

The Lighting Industry Needs to Clean Up its Act

The fluorescent lighting industry needs to clean up its act. The problems of electromagnetic fields from fluorescent lighting have been with us since the introduction of fluorescent lighting in 1940. When the first fluorescent lighting systems were installed in department stores in New York City at that time, a diffuser manufacturer told me that he had horrible vision problems and terrible headaches. To date, the fluorescent ballast industry had done almost nothing to reduce the electromagnetic fields from their products. Perhaps Federal law or legislation in one of the more progressive states could force the industry to clean up its act. A major product liability lawsuit against one of the ballast manufacturers would certainly have an effect, particularly if a court awarded significant monetary damages. The threat of regulatory action may get an industry to move. It is always better not to be regulated by a government agency. On the other hand, regulation levels the playing field for an industry.

What About Other Light Sources?

We did not have the problem of electromagnetic fields from incandescent lighting early in the electrical lighting industry. As an incandescent lamp is a purely resistive device, the current and voltage are in phase. However, a fluorescent ballast is an inductive device, so a changing electrical field causes a changing magnetic field. It should be noted that dimming an incandescent lamp can cause electromagnetic fields.

The compact fluorescent lamp is a particularly dirty source of electromagnetic fields. Moreover, many of them are used as table or desk lamps, where the source of the EMF is very close to a person's head while they are reading. The presence of EMFs has not helped their acceptance into the marketplace. High pressure sodium and metal halide discharge lamps have ballasts that give off electromagnetic fields. The new sulfur lamp is powered by a ballast, and the EMFs from its ballast will be significant unless the ballast design is changed to reduce them (6).

How Sensitive are People to Electromagnetic Fields?

I perform some of my own research to get some information on the sensitivity of people to electromagnetic fields, particularly from fluorescent lighting. The basement has sufficient daylighting so experiments can be performed during the day without the need for turning on artificial sources of light. Here is what I did. I took a 1F40 strip fluorescent fixture with a cool white lamp and a core coil ballast, and I surrounded the lamp and the fixture with a wooden box to prevent any light or glare from getting out. There are two rooms in the basement with a door between the two rooms.

With this arrangement in place, and with all other electrical equipment off in the house, I have my subjects standing 47 feet from the fixture, in the other room, with the door closed so they can not hear me turn on the switch or see me. Some subjects are able to "feel" the electromagnetic fields from this distance within one second of turning the fixture on or off!

I asked the Long Island Lighting Company to measure the electromagnetic fields from the fixture. At the surface

of the fixture, there was 200 milligauss. At three feet away, the field strength was .1 milligauss. As the magnetic field drops off as the inverse cube of the distance, the strength of the magnetic component of the electromagnetic field at 45 feet away was estimated to be between 20 and 40 nanogauss. Yet my subjects, as well as myself, were able to feel or "sense" these very weak magnetic fields.

When a sheet of a magnetic shielding material was placed at the side of the fixture in the direction of the subject, the sensation of being able to feel the magnetic fields went away.

What Do Other Studies Show?

There is a dearth of research and information on the sensitivity of human subjects to short term effects of electromagnetic fields. Two important studies will be cited below. The first study found the presence of magnetic materials in the human brain. Using an ultra sensitive super conducting magnetometer, Joseph Kirshvink and associates at the California Institute of Technology found magnetic ferromagnetic materials in the form of magnetite biomineratization in a variety of tissue in the human brain. Their research suggests that biogenic magnetite in the human brain may account for some of the biological effects of magnetic fields. The magnetite was found as nanogram sized masses of material. Their research must be taken seriously; it was done at a very prestigious university, and their findings were published in the Proceedings of the National Academy of Sciences (7).

Which frequencies of electromagnetic fields are humans sensitive to? This question was part of the subject of research conducted by William Rea, a medical researcher at the Environmental Health Center in Dallas, Texas. In his research, subjects were exposed to magnetic fields of varying frequencies from .1 Hertz to 5 million Hertz. The fields of strength was kept at .2 milligauss at hand level while subjects were tested while they were sitting comfortably upright in a chair. Of the 100 subjects originally recruited for the study, 25 were selected for double blind testing; these subjects did not react to placebos. They were challenged with the various frequency electromagnetic fields. It was found that of the 21 different frequencies, not all subjects reacted to all the 21 different frequencies, and on the average there were 11 reactive frequencies per subject.

The principal signs and symptoms produced were neurological (tingling, sleepiness, headache, dizziness, unconsciousness), musculoskeletal (pain, tightness, spasm, fibrillation), cardiovascular (palpitation, flushing, tachycardia, edema), oral/respiratory (pressure in ears, tooth pain, tightness in chest, dyspnea), gastrointestinal (nausea, belching), ocular (burning), and dermal (itching, burning, prickling pain).

Rea also found that a number of subjects reacted to the magnetic fields produced by the office lighting. It should also be noted that of the 25 subjects, 56 percent reacted to the 20K Hertz fields, 31 percent reacted to the 35K Hertz fields, and 50 percent reacted to the 50K Hertz fields. These fields are the frequencies commonly in use in the solid state ballast industry.

Rea's study concluded that there was strong evidence that electromagnetic field sensitivity exists, and that this sensitivity could be elicited under environmentally controlled conditions (8).

The Solution to the Problem

I told the library, in a letter just before the finalization of the specifications, to have shielding placed around the ballasts. The letter was sent to the architect on the basis on a problem with solid state ballasts that I had in a previous job in 1994. The recommendations in my letter, made in a passionate understanding of human needs, were totally ignored by the architect, the fixture manufacturer, and the library. My ignored advice resulted in the problems that occurred at the job site as described in the case study earlier in this paper. Both the architect and the fixture manufacturer thought I was totally nuts to specify shielded ballasts.

Ballast Design

In the design of an electrical circuit for a fluorescent ballast, a transformer, an inductor, or other magnetic components are included in the ballast. Since a fluorescent ballast contains these components, alternating current gives rise to changing electric and magnetic fields of varying frequencies. In core coil ballasts, these fields are 60 Hertz, and there may be multiples of these fields produced from harmonics in the circuitry.

Solid state ballasts contain rectifier and inverter circuits. The inverter circuit provides alternating current of between 20,000 Hertz and 65,000 Hertz to drive the fluorescent lamps. There are three types of inverter circuits. The self-excited inverter has the input winding, the output winding, and the feedback winding on the same core.

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The flip flop occurs because of saturation of the core. These circuits produce strong microphonics, and the external fields are high because of the saturation of the main core on each half cycle. A second type, the separate oscillator excited inverter, has a transformer designed to saturate at 40 Hertz. However, because the transformer is operating at 60 Hertz, it does not saturate at that frequency. It uses a separate oscillator operating at 60 Hertz feeding a power transformer. Typically these circuits produce 20DB less of external magnetic fields and microphonics. A third type, the self excited with separable saturable core, has the saturable core wired between the feedback winding of the main core and the input to the power transistor. A small transformer in the feedback circuit does the saturating but carries no substantial power.

Shielding Methods

The method of shielding the magnetic field of a fluorescent ballast is to use a magnetic shielding material. Magnetic materials are classified as soft or hard according to their ease of magnetization. Soft magnetic materials are used in devices where the change in magnetization during operation is desirable, and these materials are characterized by their low loss and high permeability. A material or metal is "ferromagnetic" if it has at least one or more of the following elements: iron, nickel, or cobalt. Magnetic permeability, or absolute magnetic permeability, μ , is defined as B/H , where B is the flux density produced in the material by the magnetic field, and where H is the intensity of the field. The permeability of ferromagnetic materials is not constant, but is dependent upon the intensity of the magnetic field to which they are exposed. The term "initial magnetic permeability" is defined as the limit approached by the magnetic permeability as B and H are decreased towards zero. Employing a ferromagnetic material having a high permeability of sufficient strength can be used to effectively provide magnetic shielding for a fluorescent ballast.

Certain alloys of nickel and iron, containing approximately 78 to 80 percent nickel, about 14 to 16 percent iron, and the remainder molybdenum, with proper heat treatment and annealing, have initial permeabilities as high as 300,000. These soft magnetic materials, when used for magnetic shielding in foil form .002" thick, can provide an attenuation factor of about 200 when used to line the ballast case. Generally, these magnetic shielding alloys are effective up to about 100 KiloHertz, as the solid state ballasts have magnetic fields of 20,000 Hertz and 65,000 Hertz. There is a method of achieving an 8,000 fold attenuation in the strength of the magnetic field. Cost considerations come into play in the selection of a shielding material and methodology.

Early in 1996, the author of this paper filed a patent application with the United States Patent Office for an electromagnetically shielded ballast to attenuate the magnetic component of the electromagnetic field.

The manufacturer of the offending ballasts in the library case study was made aware of the problems. They were sent an advance copy of a version of this paper prior to its publication. They admitted to me that there was a problem with the magnetic fields in their F40 ballasts. They said it would be necessary to redesign the circuitry of the ballast. However, such redesign may not solve the problems, and one would have to resort to shielding.

Conclusion

One of the purposes of this paper is to inform engineers, building managers, and other people in the facility management profession about the problems of electromagnetic fields from fluorescent ballasts. This problem exists, and it is real.

My standard lighting specification now includes magnetically shielded ballasts. They solve the problem of magnetic fields.

I would advise facility managers and engineers to demand magnetically shielded ballasts from ballast manufacturers. Existing installations of electronic ballasts are going to have to be removed and replaced by magnetically shielded ballasts.

Another word. Lighting is not just putting in new energy savings ballasts. Done right, one can recreate natural daylight by combining a full-spectrum fluorescent lamp with a polarizing diffuser. If you use a shielded ballast, when you walk in such a room, you will think you have a skylight in the ceiling. It can be done without cutting a hole in the roof!

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